ADAPTIVE POWER CONTROL FOR VEHICLE ENGINE

BACKGROUND OF THE INVENTION

[0001]   The application claims priority to U.S. Provisional Application No. 60/461,259, which was filed on April 8, 2003.

[0002]   Traditionally, there have been mechanical connections between a vehicle accelerator pedal and the vehicle engine. These mechanical connections typically include throttle cables that move in response to the accelerator pedal being actuated by an operator. Movement of the throttle cable controls the engine output power based on the amount of force the operator has applied to the accelerator pedal.

[0003]   The automotive industry is constantly trying to eliminate mechanical connections by incorporating electronically controlled systems into vehicles. One such system is the electronic throttle control (ETC) system. An ETC generates an electronic signal that is representative of pedal position. This information is communicated to an engine controller, which in turn determines the amount of power that should be supplied in response to a vehicle operator's request. Typically, the controller utilizes a look-up table that lists set engine responses for each accelerator pedal position. This engine control response originated from a system that utilized the direct mechanical connection where a set pedal position corresponded to a specific carburetor position, i.e. specific engine power response.

[0004]   In the past, some engine management systems have used accelerator pedal position with current engine speed to determine the engine power set point. In response to a driver power request, the pedal position and engine speed are compared in a look-up table to determine a factor of the available engine power. One disadvantage with these ETC systems

is that the systems are not capable of modifying engine power output to accommodate different driving applications or different driving habits.

[0005] There is a need for an engine management system that can accommodate driving differences. Because there is no direct mechanical connection with an ETC, it is possible to vary the response of the engine. This means that the same engine can be used in a variety of different vehicle applications by using an adaptive engine management system, which adjusts engine power output based on past driving tendencies and habits as well as using traditional ETC inputs. For example, the same engine may be used in different trucks that range from light duty trucks to heavy duty trucks. This engine may be slightly over-powered for the light duty trucks and slightly under-powered for the heavy duty trucks. Further, an aggressive driver of a heavy vehicle might drive differently than a non-aggressive driver of a lighter vehicle.

[0006] Thus, there is a need to vary the response of the engine to give the aggressive driver more response for a given accelerator pedal position while the non-aggressive driver would be given less response for that same pedal position. The engine management should be capable of learning and storing driver habits and tendencies over time to provide an adaptive engine output. A varied response is beneficial because it provides more resolution above and below nominal operating limits.

SUMMARY OF THE INVENTION

[0007] An engine management system utilizes pedal position, engine speed, and vehicle speed to determine an engine power set point. The system monitors and saves driver habits and tendencies over time to adjust the engine power set point relative to a nominal

2

engine power versus vehicle speed range. This adaptive system allows a common engine to be used in different types of vehicles by adjusting engine power output to accommodate light duty or heavy duty vehicle applications, and/or to accommodate aggressive or non-aggressive drivers.

[0008] In one disclosed embodiment, the method for adjusting engine power in response to a driver power request includes the following steps. A predetermined nominal engine power versus vehicle speed range is determined for the engine. Driver power requests are monitored over time and are compared to the nominal range to determine a driver profile. An engine power correction factor is determined based on this driver profile. A system controller uses this correction factor to adjust engine power output for subsequent driver power requests.

[0009] In one disclosed embodiment, the vehicle speed range is divided into a plurality of speed zones. The nominal engine power versus vehicle speed range extends through each of the speed zones. Each speed zone is then sub-divided into an upper zone, above the nominal engine power versus vehicle speed range, and a lower zone, below the nominal engine power versus vehicle speed range. Timers monitor the amount of time that each driver power request remains in one of the upper or lower zones for each of the speed zones to establish a plurality of zone times. Total engine running time is also measured. Each zone time is divided by the total engine running time to determine a percentage of time spent in each zone. The driver profile is determined based on these percentages. Predetermined calibration tables and known constants are used to determine a factor or gain for each of the speed zones. The factors are compared to a predetermined constant. The

3

factors are incremented by a predetermined amount if the factor is greater than the constant and decremented by a predetermined amount if the factor is less than the constant.

[0010] The factors are then used to determine the engine correction factors or gains for a vehicle high speed range and a vehicle low speed range. The high and low speed correction factors are used to modify available engine torque outputs as determined by a pedal map. The subject invention utilizes a low speed pedal map and a high speed pedal map. The pedal maps compare pedal position to engine speed to determine the available engine torque. If vehicle speed is less than a predetermined low speed value, the torque is modified by the low speed correction factor. If vehicle speed is greater than a predetermined high speed value, the torque is modified by the high speed correction factor. If vehicle speed is between the predetermined high and low speed values, the engine torque is modified by an interpolated value of the high and low speed correction factors.

[0011] The subject method and apparatus provides an engine management system that can vary engine response based on driver tendencies. The adaptive system allows a common engine to be used in different vehicle applications while also accommodating aggressive and non-aggressive driving habits. These and other features of the present invention can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Figure 1 illustrates a schematic view of an engine management system incorporating the subject invention.

[0013]   Figure 2 illustrates an engine power vs. vehicle speed graph divided into a plurality of speed zones.

[0014]   Figure 3 illustrates high and low speed pedal maps for determining available engine torque based on pedal position vs. engine speed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015]   An engine management system incorporating the subject invention is shown generally at 10 in Figure 1. The engine management system includes an accelerator pedal 12 with electronic throttle control (ETC) 14. The ETC 14 includes a pedal position sensor 16 and generates a pedal signal 18 that is communicated to a system controller 20. The controller 20 generates an engine signal 22 that controls power output for a vehicle engine 24. The operation of ETC 14 systems is well-known in the art and will not be discussed in detail. Further, it should be understood that the controller 20 could be a main vehicle control unit or a separate engine control unit.

[0016]   A vehicle speed sensor 26 and an engine speed sensor 28 communicate with the controller 20. A timing assembly 30 is used to monitor total engine running time. The controller 20 uses the vehicle speed, engine speed, engine running time, and pedal position information to determine an engine power set point. The controller 20 monitors and stores driver power requests over time to modify the engine power set point to more closely match driving habits and tendencies of the driver. This will be discussed in greater detail below.

[0017]   A driver power request is generated by depressing the accelerator pedal 12. This power request is compared to a nominal engine power versus speed range 32, shown in

5

Figure 2. This nominal engine power versus speed range 32 corresponds to a typical engine power output matched with a specific vehicle speed for the engine 24. Thus, the nominal engine power versus speed range 32 will vary for each engine and depends upon the type of engine and the type of vehicle application in which the engine will be operating.

[0018]   As shown in Figure 2, the engine power vs. vehicle speed table is divided into at least three (3) speed zones A, B, C. The nominal engine power versus speed range 32 extends through each of these speed zones A, B, C. Each speed zone A, B, C is then sub-divided into an upper zone and a lower zone. The upper zone corresponds to power requests that are greater than the nominal engine power versus speed range 32 for that zone, while the lower zone corresponds to power requests that are less than the nominal engine power versus speed range 32 for that zone. Speed zone A has an upper zone (ZONE 1); speed zone B has an upper zone (ZONE 2); and speed zone C has an upper zone (ZONE 3). Speed zone A has a lower zone (ZONE 4); speed zone B has a lower zone (ZONE 5); and speed zone C has a lower zone (ZONE 6).

[0019]   Each upper and lower zone includes a zone timer that measures the amount of time that a driver power request remains in the respective zone. Thus, ZONE 1 has a timer (TIMER 1), ZONE 2 has a timer (TIMER 2), ZONE 3 has a timer (TIMER 3), ZONE 4 has a timer (TIMER 4), ZONE 5 has a timer (TIMER 5), and ZONE 6 has a timer (TIMER 6). These timers can be incorporated into the timing assembly 30, which monitors total engine running time, or can be incorporated into the system 10 as separate timers.

[0020]   A driving cycle begins when a driver 34 turns the vehicle on and starts driving. During the driving cycle, the driver 34 will vary the pressure force applied to the accelerator pedal 12. The timers in each zone measure the length of time that the driver's

power request remains in that respective zone. Thus, each timer will have a time output for the driving cycle. The time output from ZONE 1 is T1, the time output from ZONE 2 is T2, the time output from ZONE 3 is T3, the time output from ZONE 4 is T4, the time output from ZONE 5 is T5, and the time output from ZONE 6 is T6. Each time output from the zones is then divided by the total engine driving time Tt to determine percentage of time spent in each of the zones. Thus, for example T1 is divided by Tt to determine the percentage of time Z1 spent in ZONE 1.

[0021] $T1/Tt = Z1$ $T4/Tt = Z4$

[0022] $T2/Tt = Z2$ $T5/Tt = Z5$

[0023] $T3/Tt = Z3$ $T6/Tt = Z6$

[0024]   At the end of the driving cycle, i.e. when the vehicle is turned off, the controller 20 then determines a zone factor for each of the zones Fa, Fb, Fc. The controller 20 only determines these zone factors Fa, Fb, Fc if the total engine driving time Tt is greater than a predetermined minimum amount of time. This ensures that the sample set is sufficiently large enough to provide an accurate characterization of the driver's habits and tendencies. The zone factors Fa, Fb, Fc are calculated as follows:

[0025] $Fa = (Gz_1 \times Z1) - (Gz_4 \times Z4)$

[0026] $Fb = (Gz_2 \times Z2) - (Gz_5 \times Z5)$

[0027] $Fc = (Gz_3 \times Z3) - (Gz_6 \times Z6)$

[0028] Gz_1 through Gz_6 are known calibration constants that are dependent upon engine type, vehicle application, and duty cycle and can be stored in calibration tables for access by the controller 20.

7

[0029]   Once the zone factors Fa, Fb, Fc are determined, a comparison is made to

a zone constant C. The zone constants are known calibration constants that are dependent on

engine type, vehicle application, etc., and can be stored in calibration tables for access by the

controller 20. Thus, zone factor Fa is compared to zone constant Caa. If Fa is greater than

Caa then Fa is incremented by a predetermined amount Ia (Fa + Ia). If Fa is less than Caa

then Fa is decremented by a predetermined amount Ia (Fa − Ia). This incremented or

decremented value corresponds to a gain for that zone, i.e. corresponds to a modified zone

factor.

[0030]   If Fa > Caa then Fa + Ia = Gain_Pa   If Fa<Caa then Fa − Ia = Gain_Pa

[0031]   If Fb > Cbb then Fb + Ib = Gain_Pb   If Fb<Cbb then Fb–Ib = Gain_Pb

[0032]   If Fc > Ccc then Fc + Ic = Gain_Pc   If Fc<Ccc then Fc − Ic = Gain_Pc

[0033]   Thus, for example, if the increment value was 5% and Fa was greater than

Caa, Fa would be incremented by 5% (.05). These modified zone factors Gain_Pa, Gain_Pb,

Gain_Pc are then used to determine low and high speed gains or skew factors. The low speed

gain G_{LS} and the high speed gain G_{HS} are calculated as follows:

[0034] $G_{LS} = (Gain\_Pa \times C_{LS}) + Gain\_Pb (1 - C_{LS})$

[0035] $G_{HS} = (Gain\_Pc \times C_{HS}) + Gain\_Pb (1 - C_{HS})$

[0036] C_{LS} and C_{HS} are known constants that depend on engine type, vehicle

application, and duty cycle, etc. and are stored in the controller 20.

[0037]   The low speed gain G_{LS} and the high speed gain G_{HS} are used to modify an

engine output torque as determined by use of a pedal map. As shown in Figure 3, a pedal

map uses current engine speed and pedal position to identify a corresponding engine output

torque. The subject invention modifies this output torque with the low speed gain G_{LS} and the high speed gain G_{HS} factors.

[0038] This is accomplished by incorporating current vehicle speed into the analysis. Preferably, the controller 20 utilizes two (2) pedal maps, one for low vehicle speeds and one for high vehicle speeds. Current vehicle speed V_s is measured and compared to a predetermined low speed value S_L and/or a predetermined high speed value S_H. If the current vehicle speed V_s is less than the predetermined low speed value S_L then the engine torque from the low speed pedal map is multiplied by the low speed gain, (Torque x G_{LS}). If the current vehicle speed V_s is greater than the predetermined high speed value S_H then the engine torque from the high speed pedal map is multiplied by the high speed gain, (Torque x G_{HS}). If the current vehicle speed V_s is greater than the predetermined low speed value and less than the predetermined high speed value, then the engine torque is modified by an interpolated value of the high and low speed gains G_{HS}, G_{LS} based on the vehicle speed, i.e. the engine torque is modified by estimating a gain value between the two known gain values G_{HS}, G_{LS} based on the vehicle speed.

[0039] This process is continuously updated for each driving cycle. This means that running high and low speed gain factors or skew factors are calculated over the life of the vehicle. When a driver consistently drives a vehicle at below nominal power requests, the skew factor is lowered for that vehicle speed range. A vehicle with lower weight or a less aggressive driver would be covered by this modification.

[0040] The skew factor would only be changed after the driving cycle is completed so that the driving conditions would not change while a driver operates the vehicle. Further, each of the zone factors Fa, Fb, Fc has a predetermined maximum change

limit for each driving cycle. This prevents too great of a change from occurring between immediately adjacent driving cycles.

[0041] Although a preferred embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.